FIELD ORIENTED CONTROL OF PMSM USING AURIX TRICORE MICROCONTROLLER

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Abstract: This article deals with the application of Field oriented control, or Vector control, to regulate a Permanent magnet synchronous motor. The development is going to be done configuring all the needed peripherals of a microcontroller as well as implementing standard communication protocols such as SPI. For the application of this technique of control it will be required to use PWM signals and 3-phase inverter bridge. Also several calculation and transformations to the measures will be made. The main objective is to control the speed and torque of the motor in cascade close loop.

Keywords: FOC, PMSM, current

1 INTRODUCTION

In the recent years, the use of brushless motors (BLDC) in the industry has highly increased. This fact is due to the advantages these type of motors present such us, low maintenance and high reliability [1]. But, on the other hand, there exist one kind of motor known as PMSM (Permanent magnet synchronous motor) that provides us all the benefits of BLDC in combination with an AC induction motor. Its formidable characteristics make them suitable for different applications like robotics, traction or aerospace.

These changes in the industry forced the development of new control techniques. This article is about one of them, the Field Oriented Control (FOC), also called Vector control, and its application to a PMSM employing a microcontroller.

2 THEORETICAL OVERVIEW

A further and deeper explanation of FOC will be shown in the next paragraphs besides more technical overview about the PMSM. But, first of all, it is important to know why FOC is important for engineering. Other techniques make a good control at low speeds or at high speeds, contrary to this, FOC provides smooth control at both levels [1].

2.1 PERMANENT MAGNET SYNCHRONOUS MOTOR

Amongst Alternating current (AC) motors two types can be found according to the field and rotor speed: induction and synchronous motors. In the synchronous motors, which is the case of study of this article, the speed of the rotor and the speed of the stator magnetic field are the same, they are synchronised with the frequency of the supply current [2]. This speed is called synchronous speed, it depends on the number of pairs of poles of the rotor and the input frequency. In induction motors, the rotor spins a little behind of the synchronous speed, and because of that, these ones are more complicated to control.

Moreover, there are different types of synchronous motor depending how the rotor is magnetized. The one that is interesting for this project is whose rotor is composed by permanent magnets.

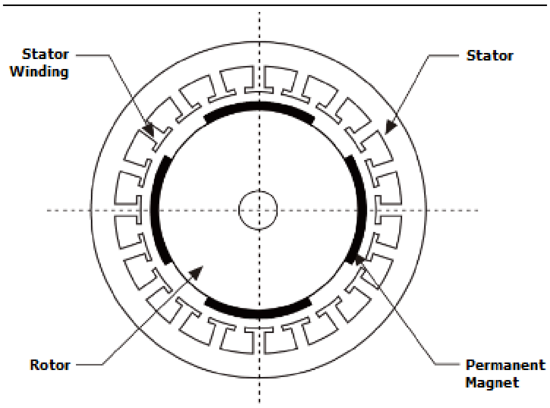

Figure 1: Section of a PMSM

PMSM are commonly known as a type of brushless DC motors, because of the construction, and induction motors, due to the windings of the stator generate a sinusoidal flux. Since its rotor is composed by permanent magnets it is not needed to be magnetized.

The advantages of these devices are its high efficiency and power density at the same time. Furthermore, they are smaller, have lower mass and moment of inertia. With the use of a sophisticated control technique, they are specially suitable for application with a fast dynamic response and torque changes [3].

2.2 FIELD ORIENTED CONTROL

The aim of this method is to express the current space vectors of the motor in a different reference system in which currents are constant for constant rotor speed [1]. If the inputs to the PI controllers are stable (DC) instead of sinusoidal signals, it makes the control smother and avoids possible delays due to errors.

To explain how to obtain the currents in such a reference system, it is needed first to talk about some basic of the motors. Suppose a simple motor with a central magnet (rotor) and three coils in the stator that are permanently energized with sinusoidal currents phase shifted by 120º. Each phase will generate its own magnetic field, and the sum of them will result in the rotating magnetic field [4]. The interaction between this field and the one created by the permanent magnets of the rotor will make it spin.

In order to control this 3-phase motor (a, b, c) designing a controller per phase will be needed, but using **Clark transformation** is possible to avoid this. This transformation obtain the currents in a two-axis stationary system (α, β). It corresponds with equations (1) and (2).

However, this two resulting currents will be also sinusoidal, thus, the problem that the reference value will be constantly changing still remains. Another transformation is needed. **Park transformation** allows to obtain two constant values of current expressed in d, q reference system, these currents will be shifted 90º and the angle φ is the rotor position.

$$I_\alpha = \frac{3}{2}\left(I_a - \frac{I_b}{2} - \frac{I_c}{2}\right) \tag{1}$$

$$I_\beta = \frac{\sqrt{3}I_b}{3} - \frac{\sqrt{3}I_c}{3} \tag{2}$$

$$I_d = I_\alpha \cos\varphi + I_\beta \sin\varphi \tag{3}$$

$$I_q = -I_\alpha \sin\varphi + I_\beta \cos\varphi \tag{4}$$

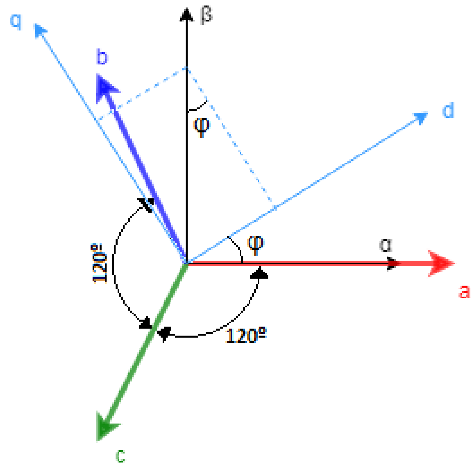

Figure 2: Clark and Park transformation

The I_q is the torque generating current (rotor), while the I_d is the magnetization current (stator). These two current vectors can be composed as unique vector, that is why it is also called vector control [5].

The next diagram represent all the steps needed to perform FOC control in a PMSM. The 3-phase currents are measured and transformed. The resulting values are compared with the reference ones to calculate the error. Passing through a PI controller the voltages that should be applied to the motor are obtained. Transforming from d, q reference system to α, β, is possible to use the output voltages to calculate PWM duty cycle that will be created with the SVM [3] [5].

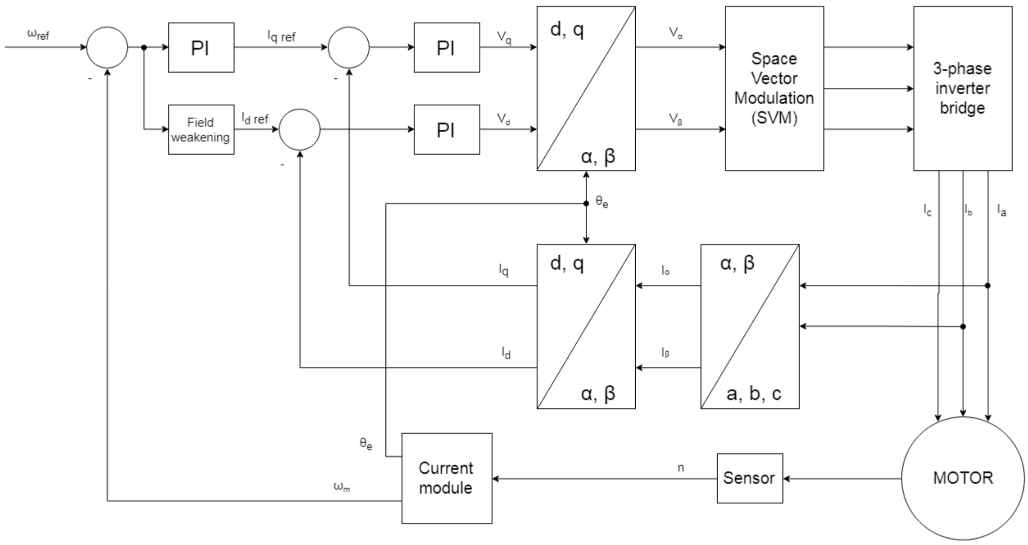

Figure 3: FOC diagram

The space vector modulation (SVM) is an algorithm that generates 3 sinusoidal PWM singals that will drive a the switches of an inverter bridge. The output of the bridge will be the currents that supplies the motor, so the time that the switches are switched on or off should be managed properly to make the average voltages coincide with the previously calculated ones [3].

2.3 IMPLEMENTATION ON MICROCONTROLLER

As it has been introduced in the title of this article, to test all this theoretical explanation about the control we will use an AURIX TriCore Microcontroller. The AURIX kit TC234 MotorCTR [6] that is been used include the motor, the processor board and a power board. All the configuration of the peripherals is done manually programmed in C language.

The processor board contains several PWM channels and provides an especial module (GTM - Generic time module) that helps to configure the 6 channels needed (3 channels plus their inverted outputs) and another extra signal for the trigger. As discussed above, all this signals are needed to drive the switches of the inverter.

On the other hand, the power board includes the 3-phase inverter bridge which outputs are connected to independent ADC channels. The ADC is used for the current sensing, three shunts are connected to the low path of the bridge [5]. Usually, only two currents are measured and used to calculate the third one. Besides, the measurement must be done when the low-side switched are closed, only then the current passes through the shunts. As the trigger of the PWM will become active in the middle of the signal it can be used for this purpose. These measures will provide the values for the close loop control.

Moreover, this kit provide us the possibility to use different sensor to measure the position of the rotor which is needed to compute the transformations. It incorporates a Hall sensor, an encoder or a resolver [6]. In this project the encoder is the one that has been selected, because of its simplicity of using and understanding. At the same time encoders provide good results and, hence, make it perfect for this application.

The communication between boards will be done using SPI (Serial peripheral interface) which is a communicating standard. It uses a master-slave architecture where the master (processor board) is unique and drives the frames for reading and writing into the selected slave (power board). It is mainly used to configure the inverter and monitor it. This interface provides a safe communication, with the possibility of reading errors and ensures data integrity [5].

3 CONCLUSIONS

To sum up, all the above devices and peripherals, as well as the interaction between them will be tested all along the project step by step. The results will be compared to theoretical simulations to ensure that this method is valid and accurate in a real application. For the moment, and taking into account all the previous information is possible to conclude that, FOC is one of the best methods to control, at the same time and in a easy way, the main parameters of a PMSM.

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